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ESTIMATION OF POPULATION DENSITIES OF MEXICAN SPOTTED OWL PREY IN PONDEROSA PINE FORESTS

by
Gerry Lynn Sauer

ESTIMATION OF POPULATION DENSITIES OF MEXICAN SPOTTED OWL PREY IN PONDEROSA PINE FORESTS

A Final Report

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Rocky Mountain Forest and Range Experiment Station

by

Gerry Lynn Sauer
Graduate Student

and

David R. Patton
Professor, Forest Wildlife Ecology

Northern Arizona University
School of Forestry

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INTRODUCTION

The Mexican spotted owl (Strix occidentalis lucida) is one of three subspecies of spotted owls in the United States (AOU 1957). Throughout its geographical range, distribution depends on availability of suitable habitat characterized by mixed forests containing old growth, mixed age and young stands (Ganey et al. 1988, Barrowclough and Gutierrez 1990). The northern subspecies (S.o.caurina) select habitats which emphasize old growth conditions (Carey et al. 1990), while the California subspecies (S.o.occidentalis) exists primarily in multi-aged conifer stands (Barrowclough and Gutierrez 1990). There has been recent research that indicates that the Mexican spotted owl may be a separate species (Barrowclough and Gutierrez 1990).

The northern subspecies was listed as threatened by the U.S. Fish and Wildlife Service (USFWS) on June 22, 1990 (Anonymous 1990). The Mexican spotted owl was classified as a sensitive species on all National Forests in Arizona and New Mexico in 1989 (Jolly 1989). Utah currently has no Forest Service classification; their first owl study is not scheduled for completion until 1994. Interim policy guidelines for Mexican spotted owl habitat management were updated on June 25, 1990. The USFWS currently classifies it as a Candidate 2 species, or one that may be appropriate for threatened listing when more information is obtained (Jolly 1989). Despite a 1989 petition for listing the status remains unchanged. The predicted December

1990 decision was not announced and is expected March 1992 (Sidener 1991). Lack of knowledge about the owls and the possibility of decreasing suitable habitat led to these political actions.

Relatively little research has been done on the Mexican subspecies, compared to the fairly extensive ecological, biological and habitat studies done on the Northern race (Forsman etal. 1984, Dawson etal. 1987, Carey 1985). While studies have shown that spotted owls need extensive amounts of old growth, why this habitat type is critical, and how this information applies to the Mexican spotted owl is unknown.

A number of hypotheses offer explanations for the old growth dependence, several involve prey availability or abundance. Others are concerned with temperature, predation, competition and availability of suitable nest sites (Carey 1985). Testing of these hypotheses is needed to provide insight into the spotted owl-old growth relationship, and the results of these tests would be useful in the formulation of Mexican spotted owl management plans and policies.

Attempts at viable spotted owl population maintenance could result in large losses in timber sale revenues and timber related jobs (Blondin 1989). The National Forest Management Act (1976) mandates that suitable habitat must be retained to ensure a viable population. The current Forest Service guidelines provide a 2000-acre territory with a 450-acre core area for all known

spotted owls. These areas are designated Spotted Owl Management Areas (SOMA); timber sales are prohibited in SOMA core areas and limited in the rest of the area. These restrictions can cause conflicts with the timber industry. Although this is more apparent in the Pacific Northwest, it is becoming increasingly important in Arizona, New Mexico and other states within the owl's geographic range. In Arizona, owls are located primarily on Forest Service lands. Approximately 55% are in areas of active or planned timber sales and 35% are on unprotected timber lands available for harvest. Less than 11% are located on reserved land (Ganey and Balda 1989).

This study was designed to examine spotted owl prey species populations to determine if relative prey densities are involved in the spotted owl-old growth relationship. The objectives were:

1. To estimate population densities of prey species for spotted owl use and non-use areas on two Spotted Owl Management Areas.

2. To compare the prey densities on use and non-use areas to determine if population differences exist.

3. To determine if there is a relationship between prey population densities and habitat components.

LITERATURE REVIEW

The spotted owl (Strix occidentalis) is a medium sized owl which inhabits forested ecosystems (Voous 1989). The three subspecies recognized by the American Ornithologists Union (AOU 1957) are differentiated by plumage coloration and geographical location. The Northern spotted owl (S.o. caurina) is found primarily in coastal British Columbia, south through western Washington and Oregon (Forsman et al. 1984, Johnsgard 1988). The California spotted owl (S.o. occidentalis) is found predominately in the Sierra Nevada mountains and other southern California coastal range areas (Johnsgard 1988, Barrowclough and Gutierrez 1990). The Mexican spotted owl (S.o. lucida) inhabits forested areas and canyons of southern Colorado, Arizona, New Mexico, Utah and Mexico (Johnsgard 1988). A recent study raised the possibility that the Mexican spotted owl may be a separate species (Barrowclough and Gutierrez 1990).

History

Prior to work done by Ganey (1988), little was known about the owl in Arizona. A literature review yielded reports on sightings and nest locations (Swarth 1908, Visher 1910, Ligon 1926,Huey 1930,1932, Campbell 1934) and notes on prey items (Huey 1913,1932, Ligon 1926, Steele 1927, Marshall 1942), but no biological, ecological or habitat information was included. Of

significance is that S.o.lucida may be the rarest subspecies (Dawson et al. 1987).

Habitat

Old growth forests are the preferred habitat of Northern spotted owls in the Pacific Northwest, with 98% of the known locations in old-growth Douglas-fir forests (Forsman et al. 1984). Mexican spotted owls exhibit a similar preference, but will utilize more habitat types and seral stages, due to the increased variability in available habitats within its range (Ganey 1988). The three main habitat types selected were mixed conifer, ponderosa pine and deciduous riparian; old-growth mixed conifer was used most often (97% of sites) in northern Arizona (Ganey 1988). In southern Arizona less mature forests were used if they contained associated patches of old growth, or steep canyons with rocky cliffs (Ganey and Balda 1989).

Old growth forests are typified by well developed, multi-storied canopies with tall dominant trees, numerous snags and an abundance of logs and wood debris (Franklin et al. 1981). The minimum values for old growth designation, as defined by the United States Forest Service (Region 3), are given in Appendix 1. Values for old growth stand characteristics used by eight spotted owls in Arizona are given in Appendix 2 (Ganey 1988). Overall, the old growth forest condition is not as well defined in the Southwest.

Research Focus

There has been extensive spotted owl research in the Pacific Northwest and the data have illustrated an unexplained spotted owl/old growth relationship (Forsman et al. 1984, Carey 1985, Gutierrez 1985a). A number of reasons for this dependence have been proposed. Carey (1985) and Gutierrez (1985a) group them into the following loosely formulated hypotheses: Availability of suitable nest sites, thermal cover, protection from predation, adaptation, and abundance and/or availability of prey. All of the above hypotheses are based on the characteristics of old growth forests and how spotted owls use them and will be discussed in more detail in the following sections.

Nest Site Hypothesis

This hypothesis is based on the fact that spotted owls, like most owls, do not build their own nests (Burton 1973). Therefore, they must use naturally occurring platforms within their habitat (Carey 1985,1990, Gutierrez 1985a) or previously abandoned nests (Forsman et al. 1984). Typical nest sites have been described with the following characteristics: Large platforms in large diameter trees, high above the ground, in cavities or jagged top snags (Forsman et al. 1984, Ganey et al. 1988). These were necessary to accommodate the large size of the

bird, and to provide protection for the young from terrestrial predators (Carey 1985).

Old growth trees provide a large number of natural nest sites due to snags, broken tops etc. and these are generally large and high off the ground because the trees are older. A Region 6 Forest Service study is being conducted to determine the impact of forest pests on spotted owl nest sites. A previous study found that a high percentage (>50%) of nests were located in "witch's brooms" caused by dwarf mistletoe infection.

Thermal Cover Hypothesis

There appears to be a relationship between site microclimate and heat stress in spotted owls (Barrows 1981). Barrows (1981) determined that the owl's narrow geographical range and habitat consistency indicated a relatively limited tolerance of environmental factors. The results of his study indicated that cool microclimates are important to spotted owls when selecting summer roosts. Almost all roosts sampled had temperatures 3-5° C lower than ambient temperatures. In another study, temperatures collected at twelve spotted owl summer roosts in Arizona averaged 5.2° C lower than other random areas (Ganey et al. 1988, Ganey 1988). The cool microclimate was especially important in areas where ambient temperatures exceeded 29°C (Barrows 1981). This is supported by a study which found that body temperatures of

spotted owls became elevated at ambient temperatures greater than 30° C (Ganey 1991).

Spotted owls studied had an upper critical temperature of <28° C and began rapid gular fluttering by 32.5° C. Gular fluttering is a form of respiratory heat exchange, analogous to panting in other animals, which can be used as an indicator of heat stress (Ligon 1969, King and McLelland 1984). Great horned owls had an upper critical temperature of 35-38° C and began rapid gular fluttering at 37° C (Ganey 1991). These data indicate that spotted owls are relatively heat intolerant and become stressed at lower temperatures (32.5° C versus 37° C). Spotted owls are less efficient at dissipating heat through gular fluttering, and thus they must depend on behavioral thermoregulation (Ganey 1991). Selecting summer roost sites within cooler microclimates is one such behavior. Owls will also move away from sunlit areas, hide below large branches, perch with their backs to the sun, expose legs and pads of feet and droop their wings when in direct sunlight.

Studies have shown that spotted owls are less tolerant of heat than other owl species, and selected areas with cooler microclimates for summer roosts. The multi-storied nature of old growth forests in the Pacific Northwest provided an ambient temperature gradient, which resulted in cooler microsites, not

found in less mature forests (Barrows 1981). This is probably also true in the Southwest.

Predation Hypothesis

There are few data to support this hypothesis which is based on sightings of Great horned owls (Bubo virginanus) and other raptors occasionally preying on both juvenile and adult spotted owls (Forsman et al. 1984, Ganey et al. 1985, Gutierrez et al. 1985, Miller and Meslow 1985). Spotted owls have been noted to avoid large open areas (Forsman et al. 1984, Gutierrez 1985a, Laymon 1985, Carey et al. 1990) and it is presumed that this is a behavioral response to predation, although reports are anecdotal. There are also conflicting reports of spotted owls response to invasion of home ranges by Great horned owls and Barred owls; sometimes they vacated the areas and sometimes they did not (Gutierrez et al. 1984, Gutierrez 1985a). Old-growth forests provide protection and reduce competition as Great horned owls prefer more open habitat types (Fisher 1974). However, this may not be true in the old growth ponderosa pine forests of the Southwest, which have become more open habitats since settlement.

Adaptation Hypothesis

The adaptation hypothesis proposes that spotted owls have coevolved with the old growth forest type and thus are

behaviorally and physiologically dependent on it (Carey 1985). Gutierrez (1985a) speculated it may also be influenced by evolutionary changes in predators, or that it may be some function of niche. Overall, there is much debate over this hypothesis which is impossible to test.

Prey Hypotheses

The prey hypothesis is separated into two components, prey abundance and prey availability (Carey 1985). Gutierrez (1985a) proposed one combined prey hypothesis. The idea of abundance is that the preferred prey are found in greater numbers in the old growth forest type. The hypothesis of availability proposes that the prey items are no more abundant in old-growth, but are more available for owl predation. The availability hypothesis is supported by a study which described the foraging behavior of spotted owls as "sit and wait" predation, where the owls scanned and dove for prey from elevated perches (Forsman et al. 1984). They were also observed pursuing prey by hopping from limb to limb. Owls probably hunt more through the middle canopy of the forest; they prey less on forest floor or open field animals (Voous 1989).

Sexual size dimorphism may be related to hunting ability (Earhart and Johnson 1970). The spotted owl males are smaller and lighter and are probably more able to hunt in dense forested areas. In general, the spotted owl is smaller than competing owl

species and will likely forage in the denser areas to avoid competition (Gutierrez 1985a). Thus, old growth, with its dense stand structure, provides more potential foraging perches, preferred forage areas, and non-competitive forage sites for the spotted owls.

To test the above hypotheses, research is needed in the following critical areas: demography, prey ecology, habitat requirement definition, juvenile dispersal, effects of habitat modification, inventory and monitoring, owl genetics and reproductive success, and vulnerability to predation (Gutierrez 1985a, Dawson et al. 1987). Research should focus on prey because the interrelationship of prey availability, abundance and distribution is probably the basis for the old growth dependence (Gutierrez 1985a). The other factors (thermoregulation, available nest sites, etc.) probably become more important as habitat fragmentation occurs and they become less available. Gutierrez (1985b) stated that prey relationships were probably a major reason for old growth dependence, and that preferred prey species should be analyzed.

Barrow's study (1985) positively related prey size to breeding success. The prey consumed by reproductively successful owls were larger than prey consumed by non-reproductive owls. Ward's (1990) study showed no differences in prey abundance between forage sites of reproductive and unreproductive owls. In discussion, he stated that this may have been due to high

variability in his study. He also found that males foraged in areas which were more abundant in prey of the genera Neotoma and Peromyscus.

Spotted Owl Reproductive Biology

Pairs of owls of all subspecies normally begin to roost together near nest sites in late February or March. Eggs are laid at regular three day intervals in March or early April. Incubation lasts approximately 32 days. During the incubation and brooding periods, the males provide all food for the pair. Later, both parents provide food until the juveniles disperse. This occurs in September or October, when the young are about 35 days old (Forsman and Meslow 1986). Until fledging, food demands are extremely high and meeting those demands requires a continuous food source.

Preferred Prey Items

The diets of both the Northern and California subspecies are composed primarily of large semi-arboreal rodents, but variation occurs between regions. Mammals comprised over 90% of the biomass consumed; northern flying squirrels (Glaucomys sabrinus) and wood rats (Neotoma spp.) (Forsman et al. 1984) are the biggest contributors. Reports of food items of the Mexican subspecies include insects, rodents, squirrels, other owls, and game birds (Huey 1913,1932; Ligon 1926, Steele 1927, Marshall 1942). Mammals comprised over 90% of all prey items consumed

(Fisher 1974, Ganey 1988, Ganey and Balda 1988). In northern Arizona, wood rats, white-footed mice (Peromyscus spp.) and voles (Microtus spp.) were the major prey items reported (Ganey 1988). Descriptions of prey species habitats and their biology are necessary to understand the owl-prey-habitat relationship.

Neotoma

Rodents of the genus Neotoma are commonly called wood rats or pack rats (Olin 1954). They are primarily nocturnal, do not hibernate and are found throughout the United States (Olin 1954, Hoffmeister 1971, Van Gelder 1982, Vaughan 1986). Wood rats resemble common house rats but have exceptionally large, silky ears and a lightly furred tail (Olin 1954).

There are five species found in Arizona: N. albigula, N. stephensi, N. mexicana, N. lepida and N. cinerea. Hoffmeister (1986) provided biological and physical characteristics for identifying these species in the field.

Home ranges are usually under 2 ha, although males will travel more widely during the breeding season (Van Gelder 1982). The main breeding season is early spring and summer. The gestation period is 27-35 days, and Neotoma can produce 1-2 litters/year (Streubel 1989). Densities can vary widely, but average 2-30 animals/ha (Vaughan 1986). Cyclic population fluctuations can occur.

Peromyscus

Members of the genus Peromyscus are commonly called deer, cactus, or white-footed mice (Olin 1954, Reichman 1974, Mihok 1986). They are widely distributed throughout North America (Sullivan 1986), and can be found in every life zone in the Southwest (Olin 1954). Deer mice are strictly nocturnal and are active year-long. There are at least 17 species in the United States. Of these, eight are found in Arizona: P. maniculatus, P. leucopus, P.truei, P. eremicus, P. merriami, P. crinitus, P. difficilis and P. boylii. Peromyscus resemble house mice but are usually gray above with white under parts and feet, and possess extremely large ears and haired tails (Olin 1954). Home ranges vary with terrain, but average 0.13 ha for Peromyscus spp. (Gottfried 1986), 0.2-1.2 ha for P.maniculatus and 0.2-0.6 ha for P.leucopus (Burt 1976). The main breeding season is February to November. The gestation period is 23-28 days, and the females may produce up to 9 litters/year (Streubel 1989). Density estimates range from 1-6 animals/ha (Allen 1979, Jameson 1951). Cyclic population fluctuations can occur.

Microtus

The animals in the genus Microtus are commonly called voles or meadow mice (Caras 1967), and are widely distributed throughout North America (Sullivan 1986). They are typically small stocky creatures, with comparably large heads with small

ears, and short legs. A primary distinguishing feature is their short (1-3 inches) furred tail (Caras 1967). Voles are both nocturnally and diurnally active and do not hibernate (Beacham 1986, Hilborn 1986). Microtine rodents exhibit large 3-4 year cyclic population fluctuations (Sullivan 1986). Activity is sometimes decreased on cold, clear nights (Bider 1968).

Of the 11 species in North America (Getz 1986), three are found in Arizona: M.montanus, M.longicaudes, and M. mexicanus. M.mexicanus has the widest habitat range of all microtines in Arizona and is commonly found in dry, grassy areas adjacent to ponderosa pine stands (Hoffmeister 1986). Microtine rodents have a March-September breeding season; gestation is about 20-23 days (Hoffmeister 1986). Densities are variable and range from 1-100's of animals/ha; home ranges are about 20-50 m (Getz 1986).

Examining Populations

Studies of wildlife populations are generally undertaken to gain knowledge necessary to solve specific problems. These problems can be different and the study methods utilized will depend on the desired objectives. Many types of data can be collected for individual species. If the goal is determination of species presence or absence, animal sign can be examined, or calling surveys, or visual searches can be conducted. The methods for determining densities of animal species include

count/searches, line searches and mark-recapture or other trapping procedures.

Mark-recapture is a method that involves the live trapping and marking of individuals of a population followed by a recapture period at some later time. Density estimates are based on the ratio of marked to unmarked animals in the recapture sample. A mark-recapture method should be used when an accurate density estimate is desired, but a complete census is not possible. A mark-recapture study is also effective when minimal disturbance of the study population is desired. If designed correctly, mark-recapture studies can be used to examine all types of animal populations.

The ultimate goal of a mark-recapture study is accurate estimation of population densities. This is sometimes difficult, due to the number of estimation methods available and the assumptions which must be met. All methods will exhibit some bias when applied to certain data sets. Further, estimates based on live trapping data tend to underestimate true numbers for many species (Eberhardt 1969) and mark-recapture studies are not very robust to departures from assumptions (Caughley 1977). Determination of sample sizes required for estimation methods usually requires prior knowledge of the population or a preliminary study. The most accepted method for determining sample size is illustrated by the variance formula of Snedecor

(1956). Of the multitude of estimation methods available, the Lincoln-Petersen Index is the simplest and the Jolly-Seber estimator is one of the most complex.

Lincoln-Petersen Index

The Lincoln-Petersen Index involves one mark and one recapture period. The first sample is a random sample of individuals of the population. They are marked and returned to the population where they mix with the unmarked individuals. The second sample is again random, and contains a mix of marked and unmarked individuals. The size of the population is estimated using the ratio of marked to unmarked individuals.

Jolly-Seber Estimate

The Jolly-Seber estimation method is based on the Lincoln-Petersen index, but a number of mark and recapture sessions are required. The Jolly-Seber estimation method is more realistic than the Lincoln-Petersen index. It compensates for different types of populations (open or closed), and allows for varying survival rates and losses on capture. The basic premise is the same; animals are marked and recaptured at some later time, however, small numbers of recaptures may cause increased bias. To calculate estimates, the history of recaptures must be known for each animal (Caughley 1977).

Suggested Trapping Design

Neotoma

Live trapping of Neotoma can be done year-long (Vaughan 1986). The preferred trap is a Sherman box trap (7.5 x 7.5 x 25 cm) (Pyc 1984, Vaughan 1986), although pitfall traps can be used (Taber and Cowan 1961, Block et al. 1988). Box traps can be purchased commercially; pitfall traps are made by burying buckets (Block et al. 1988, Szaro et al. 1988), or aluminum cans (Taber and Cowan 1961) in the ground. Traps should be baited with rolled oats and/or peanut butter; raisins or apple pieces should be included for moisture in warm weather (Vaughan 1986). Curiosity bait, such as sparkling objects, can also be used (Taber and Cowan 1961).

Since wood rats are not regularly spaced, a trapping grid may be ineffective. Traps are usually placed at entrances of dens (Vaughan 1986), which are easily identified by the large mounds of debris covering them (Olin 1954), or every 8 m in places where activity is noted. Activity is defined as presence of dens, debris or droppings (Pyc 1984). Traps should be set at night and checked early in the morning to prevent death. Animals may be marked by toe clipping and released at point of capture (Pyc 1984, Vaughan 1986).

Peromyscus

Live trapping should be done during warmer months, (Mihok 1986) when populations peak, to ensure adequate numbers of captures. The preferred traps are Longworth or Sherman live traps (Kitchings and Levy 1981, Gottfried 1986, Mihok 1986, Sullivan 1986, Adler and Wilson 1987, Smith and Sloan 1988). Pitfall traps are not recommended for mark-recapture studies as Peromyscus become trap shy (Taber and Cowan 1961). Effective baits include sunflower seeds, oats, peanut butter or any combination of the three. A wad of cotton should be added to decrease deaths due to cold (Kitchings and Levy 1981, Gottfried 1986, Mihok 1986, Sullivan 1986, Adler and Wilson 1987, Belk, Smith and Lawson 1988, Smith and Sloan 1988).

Trapping grids are often used, with a minimum grid size of 1.0 ha. The recommended spacing between trap stations is 10-20 m (Mihok 1986, Sullivan 1986, Belk et al. 1988, Smith and Sloan 1988), and traps should not be placed in exposed sites (Gottfried 1986). Trapping should be done overnight in summer, as mice perish rapidly in metal traps. To ensure ability to tend traps properly, a maximum of 100 traps/person/day is recommended (Sullivan 1986). Animals can be marked by toe clipping, ear notching, or ear tagging with fingerling fish tags, and released at point of capture (Kitchings and Levy 1981, Gottfried 1986, Mihok 1986, Sullivan 1986, Adler and Wilson 1987, Belk et al. 1988).

Microtus

Live trapping can be done in all seasons and the preferred traps are Sherman and Longworth box (live) traps, or pitfall traps (O'Farrell 1974, Randall 1979, Belk et al. 1988, Desy,Batzli and Jike 1989). Beacham (1986), Hilborn (1986), and Sullivan (1986) suggest a combination of pitfall and box traps. This is to ensure a more complete enumeration of the population, as the former tends to trap smaller voles while the latter traps larger. Species of Microtus can become trap wary (Hilborn 1986), so prebaiting of box traps for one to two weeks is suggested (Beacham 1986, Sullivan 1986). Effective baits are oats, carrots or other vegetables, cracked corn, peanut butter, or any combination of the above. Cotton should again be added (O'Farrell 1974, Cole and Batzli 1978, Randall 1979, Beacham 1986, Hilborn 1986, Sullivan 1986).

Trapping grids (O'Farrell 1974, Cole and Batzli 1978, Sullivan 1986, Belk et al. 1988, Desy et al. 1989), or transect lines (Sullivan 1986) can be used. A minimum grid size of 0.5 ha is suggested by Sullivan (1986) with station intervals of 5-15 m (O'Farrell 1974, Cole and Batzli 1978, Sullivan 1986, Belk et al. 1988, Desy et al. 1989). Again trapping should be done only at night in summer as voles will perish rapidly (Beacham 1986, Hilborn 1986, Sullivan 1986). Animals can be marked by toe clipping (Beacham 1986, Belk et al. 1988), but ear tagging with fingerling fish tags is preferred, and released at point of

capture (Beacham 1986, Hilborn 1986, Sullivan 1986, Desy et al. 1989).

Summary

The literature reviewed demonstrated a strong spotted owl--old growth relationship. The reason for this is not known but a number of hypotheses have been formulated (Carey 1985, Gutierrez 1985). Several researchers believe that prey base studies are high priority. Detailed habitat and behavioral information is necessary to conduct quantitative studies of the prey species.

METHODS

Study Design

This study was conducted on two Spotted Owl Management Areas (SOMA's) (Schultz Creek and Weatherford Canyon) on the Peaks Ranger District of the Coconino National Forest (Figure 1). These two SOMA's are primarily comprised of mixed conifer and ponderosa pine vegetation. The areas were selected because detailed owl home range and telemetry maps, aerial photographs and other resource information was available. The study areas were not randomly chosen. The primary study was conducted from May to September 1991, but a preliminary study was done from July to September 1990. The owl "young rearing" season was selected as a study period because demands for food are high at this time. Also, there were no prey animal biological restrictions. All species are active year long, and have multiple, variable breeding seasons which are difficult to predict, and avoid.

The primary prey animals of the owl were determined to be of the genera Peromyscus, Neotoma, and Microtus based on percentage of 1193 prey items (Ganey 1988). Peromyscus were the most trapped in the study area (personal observation), thus this genus was used as the basis for trapping criteria.

Sampling Design

Owl use areas were determined within each SOMA using telemetry maps (Ganey 1988). Areas with high concentrations of

sightings were designated as use (feeding) areas. Non-use areas were defined as areas within the SOMA where no sightings were recorded. Six sites were selected for each SOMA; three use and three non-use. Non-use areas were randomly selected using a numbered grid overlaid on aerial photographs of the SOMA. Use areas were not randomly selected but were taken directly from telemetry maps. The twelve sites were located on USGS topographical maps (1:24000 scale) and aerial photographs. All sites were determined to be of approximately equal crown closure (40-70%); tree species composition was not known at the time the sites were selected for study.

Each use and non-use site was allocated three, one ha live trapping grids to determine prey population densities. Site center was located on the ground by using a compass and an altimeter. Each grid was 120 paces from the site center at compass bearings of 120°, 240° and 360° and oriented in the four cardinal directions. This design gave a minimum distance between grids of about 185 m, or approximately twice the home range distance of Peromyscus, to ensure independence of samples.

Trapping Design

Live trapping grids consisted of 50 (8 x 8 x 20 cm) Sherman live traps in a staggered configuration (Figure 2)(Patton et al. 1976). Larger Sherman traps (8 x 9 x 30 cm) replaced missing and broken ones, and were also used in possible Neotoma habitats.

Trap stations in each line were located at approximately 22 m intervals. Traps were placed within 2 m of the trap station, near trees, rocks or logs. All traps were covered with litter, bark and other natural materials and were baited with moistened rolled oats, cracked corn and sunflower seeds. Rolled oats were eliminated in mid-June due to rainy weather. Traps were left open 24 hours and checked only in the morning. Cotton was added for bedding. Animals were trapped for five nights on each grid. This trapping design was chosen because:

1. A 1 ha minimum plot size is recommended for Peromyscus (Sullivan 1986).

2. The design should provide 4 traps per home range (White et al. 1982). This computes to a trap station interval of about 15 m for Peromyscus. The staggered trapping grid gave a nearest neighbor trap distance of about 15.8 m.

3. All literature sources reviewed recommended the bait used. To decrease trap deaths due to ants and increase trap efficiency, peanut butter was omitted.

4. Increased mortality occurs when traps do not contain cotton (Call 1982,1986 Sullivan 1986).

5. A minimum of 500 trap nights per habitat type is suggested (Call 1982). A minimum of 5 trapping occasions is recommended (White et al. 1982). The accepted method of calculating trap nights is multiplication of number of traps by number of nights. For this study there were 50 traps for five nights which gave 250 trap nights/grid. There were three grids per site which yielded 750 trap nights per use site. The time period the trap was available for animal entry was considered a session or occasion. For this study, the five nights the traps were left open would be the trapping occasions.

6. Jolly-Seber analysis requires a minimum of 4 trapping occasions (Ricker 1975).

Prey Data Collection

For data collection a Schnabel mark-recapture technique was used. The Schnabel technique is one in which prey animals trapped are examined for marks. Every animal is then given a new mark before it is released, or has its old mark recorded (Seber 1973). Traps were examined in the morning. All non-prey animals were noted, not marked, and released. All prey animals were tagged in one ear with numbered fingerling fish tags. Left and right ears were tagged on alternating days. Tag number (left or right ear) and trap number were recorded. The result was a complete trap history for each animal. Total body length and weight, tail length, hind foot length and ear length were measured for species determination. Animals were released at the point of capture and the final hiding place was identified.

Habitat Data Collection

Three 0.04 ha circular plots centered at randomly selected trap stations were sampled for each live trapping grid. Trees were visually identified to species and diameter measurements were recorded at breast height (DBH) with a Biltmore stick for all trees greater than 10.2 cm. Crown closure was determined using a spherical densiometer. Readings were recorded in the four cardinal directions at each trap location by noting hits on

the densiometer intersections. The total number of hits was multiplied by 1.47 to determine percentage foliage cover. Down logs within the grid were tallied and measured lengthwise with a 100' cloth tape. Two intersecting pace transects the width of the plot were used to record hits on grass, litter, shrub, rock, forb, soil, etc.

Prey Data Analysis

This study was conducted on open rodent populations in which there were no natural boundaries, thus entries to and exits from the area could occur. Open population models allow for births, immigrations, deaths and permanent emigrations; most closed models do not. All capture-recapture models require that basic assumptions be met and the following are applicable to most models:

1. Marks are not lost and are correctly recorded on capture.
2. The trapping procedure does not alter the animal's chance of recapture.
3. The trapping procedure does not effect the animal's chances of dying or emigrating.
4. All individuals have the same probability of being trapped.
5. All animals have an equal probability of dying or emigrating.

In the Lincoln-Petersen closed population model there is an additional assumption that there are no births, deaths,

immigrations or emigrations. For this study, all assumptions are assumed to be valid, although the populations were not closed.

Population density estimates were made by using Begon's (1979) Jolly-Seber model. The Jolly-Seber model estimates population parameters over long periods of time, allows for varying rates of survivability and losses on capture, and is often the most appropriate mark-recapture model (Begon 1979). Begon's and Ricker's (1975) Jolly-Seber models were integrated in this study due to small numbers of recaptures. The following formulae were used:

$$M=(m+1)+\frac{(z)(r+1)}{(y+1)} \quad \text{and} \quad N=\frac{M(n+1)}{(m+1)}$$

where, M=number of marked individuals available for capture,

m=number of recaptured marks,

z=number of individuals marked previously, not captured on that day but caught subsequently,

r=number released,

y=total number of r caught subsequently,

N=population size,

n=number captured.

These models estimated population densities on a per day basis for all days except the first and last. These daily estimates were averaged to determine a mean value for each grid. Jolly-Seber estimates have increased bias when y and m values are < 3

(Ricker 1975); I assumed this would occur in this study. Therefore, a second model was also used to estimate populations.

Population densities were also estimated by using the Lincoln-Petersen method. This method of estimation is simple but it is the basis for most other models (Caughley 1977). Only one mark and one recapture period is necessary; the population is closed. Although the study population was not closed, the Lincoln-Petersen index model was selected for comparison to the complex Jolly-Seber model; this was seen in the literature (Lidicker 1966). The following formulae were used:

$$N = \frac{M(n+1)}{m+1} \qquad S.E. = \frac{M^2(n+1)(n-m)^{0.5}}{(m+1)^2(m+2)}$$

where, N=the unknown population,

M=the number marked,

n=the size of the second (recapture) sample,

m=the number of marks recaptured,

To obtain two time periods, the data were pooled (Hayne 1949, Davis 1986). Days 1 and 2 were considered the marking period, and Days 3, 4, and 5 were considered the recapture period.

Relative abundance estimates were also determined for each grid as number trapped/ha/trap period. Relative abundance estimates are usually expressed in terms of catch effort, and are considered an index of density (Caughley 1977).

Finally, the number of prey species trapped on each grid was determined. Since different species have different habitat requirements and preferences, these values could be considered indicators of habitat diversity within grids. This within grid diversity could then possibly be related to the concept of prey availability.

Habitat Factor Analysis

DBH measurements for each tree were converted to basal area (BA) values. BA is defined as the total cross-sectional area of a tree stem at 1.4 m above ground level. The per tree BA values were converted to m^2/ha values for each grid. Percent frequency of occurrence of grass, litter and rock was calculated for each grid from pace transect data. Tallies of down logs were used to compute number of down logs/ha for each grid. The following were also calculated on a per grid basis: total number of trees/ha, number of trees/ha >50 cm DBH, number of trees/ha >35 cm DBH, number of trees/ha >15 cm DBH, and average diameter of all trees. These DBH values were arbitrarily selected. Finally, the number of tree species present on each grid was determined.

Statistical Procedures

Jolly-Seber estimates of prey populations were analyzed using a nested one factor analysis of variance (ANOVA) (Vann 1972) to test for differences between use and non-use (owl

feeding and non-feeding) areas and to determine if grid values could be pooled. Then, grid values for prey density estimates, number of prey species and habitat components were summed to determine average values for the 12 sites. These average plot values were analyzed by single factor ANOVA using SYSTAT software (Version 5.1, SYSTAT, Inc.) to test for differences between use and non-use areas. Correlation analysis was done using SYSTAT software to look for relationships between prey number estimates and habitat components. The number of prey species present on each plot was also included in the analysis. Correlations with r values greater than 0.500 were tested using SYSTAT's simple linear regression model to determine if any significant relationships existed. All other prey estimate/habitat component pairs were also tested using regression analysis. For all ANOVA's and regressions, the validity of underlying assumptions was examined using residual analysis. I did not accept the null hypothesis when the probability associated with test statistics exceeded 0.05.

RESULTS

A total of 288 prey animals were trapped in 9000 trap nights from June 1 to August 30 1991. Distribution among species was as follows: Peromyscus maniculatus 87%, P.leucopus 6%, P.boylii 5%, P.truei <1%, Neotoma mexicana 1.4%, Microtus mexicana <1%. Ground squirrels (Spermophilus spp.) and chipmunks (Eutamias spp.) were also trapped; numbers were not recorded because these were not common prey species. For population analysis all species of Peromyscus were pooled. Neotoma and Microtus populations were not estimated due to low capture rates.

Jolly-Seber population density estimates for Peromyscus are presented in Table 1. Lincoln-Petersen values with associated standard errors are included for comparison purposes. The null hypothesis was accepted when Jolly-Seber data were analyzed by a nested ANOVA with $P > 0.05$ ($F=.0978, df=1,10$). The conclusion is there are no differences in prey density between use and non-use areas.

Average plot values for Jolly-Seber and Lincoln-Petersen density estimates and relative abundance (RA) values are presented in Table 2. The null hypothesis, of no significant difference, was accepted when single factor ANOVA was used to analyze the three prey estimates (Table 3) and $P>0.05$. Again, the conclusion is there are no differences in prey density values between use and non-use areas using these estimators. There was also no significant difference between the 12 use areas when

single factor ANOVA was used to test the number of prey species trapped ($F=0.039$, $P=0.848$, $df=1,10$).

Average plot values for habitat components are presented in Table 4. Single factor ANOVA was used to test for habitat component differences between use and non-use areas. All study sites were randomly selected; a certain number of plots were not specifically placed in a vegetation type. This resulted in lots of variability, however, the results (Table 5) showed no significant differences between use areas for 11 of the 12 components measured and analyzed. Number of tree species present was significantly greater at use sites ($F=20.039$, $p=0.001$, $df=1,10$). In non-use areas the vegetation was primarily composed of ponderosa pine (Pinus ponderosa). In use areas the composition was more diverse. Species present included ponderosa pine, white fir (Abies concolor), Douglas-fir (Pseudotsuga menziesii), alligator juniper (Juniperus deppeana) and Gambel oak (Quercus gambelii). Since there were no other differences between habitat components, they were pooled to determine stand characteristics for spotted owl use areas (Table 6). Average elevation was 2450 m for use sites and 2385 m for non-use sites.

A Pearson correlation matrix applied to the complete data set suggested several relationships: Negative correlations between relative abundance (RA) and basal area and Lincoln-Petersen estimates and percent rock, and a positive correlation between relative abundance and percent litter (Table 7).

Simple linear regression (SLR) analysis of the above correlations were not significant for the RA and basal area model ($F=3.870$, $P=0.077$, $df=1,10$) or for the RA and percent litter model ($F=3.342$, $P=0.097$, $df=1,10$). There was a significant linear relationship between the Lincoln-Petersen estimate and percent rock ($F=10.052$, $P=0.010$, $df=1,10$). The data set yielded no other significant relationships between prey estimates and habitat components.

The requisite ANOVA and SLR assumptions were determined to be valid through examination of the residuals. An exception was seen in the probability plot of residuals in the SLR model with the Lincoln-Petersen estimate as the dependent variable and percent rock as the independent variable. This plot showed some deviation from the normality assumption, but since ANOVA is robust to moderate departures from normality (Johnson 1987), the model was not changed.

DISCUSSION

Spotted Owl Use and Prey Densities

One of the objectives of this study was to determine if there were significant differences in prey densities between owl foraging areas and nonforaging areas. The *a priori* assumption was that prey densities would be greater in areas owls selected for foraging. My results indicated there were no differences at the 0.05 level of probability. Low statistical power, biased or inaccurate population estimators and inaccurate study site selection could be explanations for this departure from what was expected.

Statistical Power

In cases where one does not reject the null hypothesis, a test of statistical power is often desirable. Power is an indication of how accurately the statistical test detected true differences among treatment means (Zar 1984). Power calculations require some prior knowledge of related population parameters. Since this information was not available, power of statistical tests was not calculated. However, since low power values have been reported for statistical tests used to analyze similar small mammal data (Ward 1990), I assumed that my tests were not very powerful.

Population Estimators

It is appropriate to utilize Jolly-Seber estimates when a realistic estimate is desired, and when population type (open or closed) is not evident. However, problems may arise when recapture frequency is low. Jolly-Seber estimates have increased bias when small numbers of animals are recaptured (Ricker 1975). Such was the case in this study; I did not meet the minimum recommended values for y and m in over 70% of my estimates. Further bias can also occur when assumptions are not met.

The primary difference between various population estimators is the assumptions which must be met for results to be accurate. Selection of estimators must be such that assumptions are not violated as small violations can produce large errors (Caughley 1977). Although validity of assumptions is extremely important, testing them is very difficult and often beyond the scope of the investigation (Call 1986). I attempted to test the equal catchability assumption, which some researchers believe is the most important (Caughley 1977), but I was not successful due to the small frequency of recaptures I obtained. Through study design, I strived to minimize the possibility of violating other assumptions. For these reasons, all assumptions were assumed to be valid.

If underlying assumptions were violated or the improper method of estimation were selected, the results could be inaccurate population estimates. However, this type of

inaccuracy would probably be of little significance in this study, since the same methods were used to estimate both use and non-use (feeding and non-feeding) areas, and the prey populations should be similar. Any errors would be consistent among all plots, and this will allow for clear comparisons between the use and non-use areas.

Visual comparison of the Jolly-Seber and Lincoln-Petersen densities showed that the two methods gave similar population estimates; 44% of the Jolly-Seber estimates fell within one standard deviation of the Lincoln-Petersen estimate, and 92% fell within two. I conclude that the simpler Lincoln-Petersen estimate could be utilized in studies where the recapture rate is low, and the Jolly-Seber estimate might be biased. The calculations of the Lincoln-Petersen estimate are more easily understood, standard errors of the estimates can be easily calculated, and the trapping period may be decreased.

Selection of Study Sites

Forest Service aerial photographs taken in 1978 and Ganey's (1988) telemetry maps were used for selection of study sites. Since management activities are continuing on the Coconino National Forest, changes may have occurred which could render the above out of date. However, it was used because this was the only resource information of this type available. Timber harvest is a management activity which could effect this study.

Harvest activities could cause changes in both the densities of small mammals within the SOMA and in use of the area by the resident spotted owls.

Small mammal densities can be greatly impacted by logging activity. Small mammal studies done in Douglas-fir forests of the Pacific Northwest have shown that Peromyscus densities are higher in logged than virgin areas (Tevis 1956, Gashwiler 1959,1970). Similar results have been shown for loblolly forests in the Southeast (Trousdell 1954), and for ponderosa pine forests in Arizona (Goodwin and Hungerford 1979). If owl behavior is dependent on abundance of prey, corresponding patterns of use may have changed. Thus, use and non-sites may have been labeled incorrectly. I attempted to compensate for this by not placing study sites within timber sale boundaries, but some sites were adjacent to harvested areas. The magnitude of changes within the SOMA due to management activities was not known and could not be corrected for.

Habitat Components and Prey Densities

Another objective of this study was to determine if relationships between prey densities and habitat components existed. The results showed only one significant linear regression relationship; between the Lincoln-Petersen estimate and percent rock present in the plot.

These results conflict with the conclusions of a previous study (Goodwin and Hungerford 1979) which found a correlation between abundance of deer mice and area covered by down logs and stumps (ft^2), which could be considered an indication of the amount of cover available. The difference could be due to dissimilar measurement techniques. I used a count of down logs and not an area or volume measurement of them.

Analysis of Habitat Components

All animals have specific needs which must be met to ensure their survival. Food and cover are the two most important to small mammals. These needs are met by the physical factors of the habitat and can be quantified by measurement of habitat components. Vegetation and vegetation structure are often the most important habitat components determining wildlife numbers (Anderson and Ohmart 1986).

Since I anticipated prey densities would be greater in feeding areas, I also assumed that habitat characteristics would differ. Overall, this was not the case, however, this could be due to the time period covered by the study. Vegetation studies which cover only one season or one year may lead to false conclusions regarding vegetation and wildlife relationships (Anderson and Ohmart 1986). This could not be tested, due to temporal constraints, so I concluded that there were no habitat

differences between owl forage and random areas since only one factor was significantly different.

Comparison Analysis of Stand Data

The values for various stand characteristics measured in this study were compared to values for forage and random areas from a previous study (Ganey 1988); the values are presented in Table 8. The stand characteristic values from this study were all below the values previously recorded for forage areas. By visual examination, they appeared more consistent with values given for random areas than for forage areas. I did not do a comparison with roost and nest site values. Forage sites exhibit the most variability; since my values were not consistent with forage site values, they probably are even less so with roost and nest site values. I also compared my study sites with the minimum values for old-growth designation by the USFS (Region 3). Only 50% of my study sites met the requirements; low stand densities were the primary reason the requirements were not met.

Average study site elevations were higher than reported for areas where owls were located. They were within the range of elevations given (1830-2745 m) for sites occupied by owls. Elevation is one habitat variable that is likely to be important to spotted owls (Ganey 1990).

Recommendations

All small mammal studies have a number of inherent difficulties; most are caused by the highly variable and flexible nature of the animals. Further problems are encountered when attempts to estimate population densities are made. Two things, animal mobility and changing populations, are the most problematic, however, some study design compensations can be made.

Mobility

Small mammals can be highly mobile and their movements can be difficult to predict. In many species, males will travel widely during the breeding season, thus their home ranges will be larger at those times. Females of these species are often polyestrous, and their seasons will vary due to weather, resource availability, etc. Also, females will not forage or leave the nest often until the young are weaned. So, estimating the size of the home range becomes difficult. Independence of samples is required for statistical analysis, and may be difficult to achieve when the minimum distance between study areas cannot be determined. Also, many estimation methods require that all animals have equal catchability. If females are less likely to be trapped, this assumption is not valid.

Consequently, attempts to conduct studies during non-breeding seasons should be made. If this is not possible, as is

often the case, studies for comparison should be conducted at the same time of year. Also, the sex of animals trapped could be recorded and data could be examined using chi-square analysis to determine if there is a difference in trappability due to sex.

Population Fluctuations

Small mammal populations often exhibit cyclic fluctuations; this is especially true in microtine rodents. Microtine population densities can range from <1 to hundreds/ha during a population phase (Getz 1986). During peak population periods marginal habitats will be used to decrease competition. This could result in high densities of animals where there usually are few or none.

Thus, short-term studies may lead to inaccurate estimates of animal densities. Long-term studies which last the length of a population cycle (3-5 years for Microtus), would yield a more accurate picture of the population dynamics of the species. Long-term studies may also result in clearer descriptions of animal/habitat relationships, because only the preferred habitats will be used at low population densities.

Summary of Recommendations

The variable nature of small mammals makes estimation of population densities difficult. Often, assumptions of estimation methods are not valid, and short-term studies yield inaccurate results. For these reasons, I would recommend long-term studies

(3-5 years) for both comparison type studies and studies where quantitative data on prey density is required to meet management objectives. I would recommend use of the simplest estimation method applicable to the goals of the project. If time and personnel are not limiting, trapping until 90% of the animals trapped are recaptures, would provide the most unbiased estimate of the population. However, this prevents scheduling of trapping sessions; you cannot predict exactly how long it will take. So, if time constraint exist, the Lincoln-Petersen method is probably the method which should be used. Since only one mark and one recapture period are required, the time for each sample is decreased, and a larger sample size can be obtained. When examining highly variable populations, a large number of samples is desirable.

Summary

I found no significant differences in prey densities between feeding and non-feeding areas. Another, comparable study had similar results, but calculation of power showed that the tests had a low probability of detecting true differences between treatment areas. Further, the materials used for site selection were not current. Management activities, such as timber harvesting, may have resulted in changes within the SOMA which could not be accounted for. I also found no significant correlations between prey densities and habitat components. This

conflicts with a similar study which showed a positive correlation between Peromyscus densities and area covered by down logs and stumps. There were also no differences in habitat component values between use and non-use areas.

For these reasons, I conclude that my study was probably not powerful enough to detect true differences in prey densities and habitat components between use and non-use areas; I do not conclude that such differences do not exist. Also, I conclude that relationships may exist between habitat components and prey densities, but this study failed to detect them. However, the original assumptions may be valid and the results could be correct as shown. If population densities were at a peak, all available habitats would be used by the prey animals. Areas which were previously not heavily populated would be so now, resulting in similarities in prey densities between feeding and non-feeding areas. Further, habitat component measurements showed no differences between use and non-use areas. If sites were improperly labeled, there may be only one type present. Thus, prey densities would not be different.

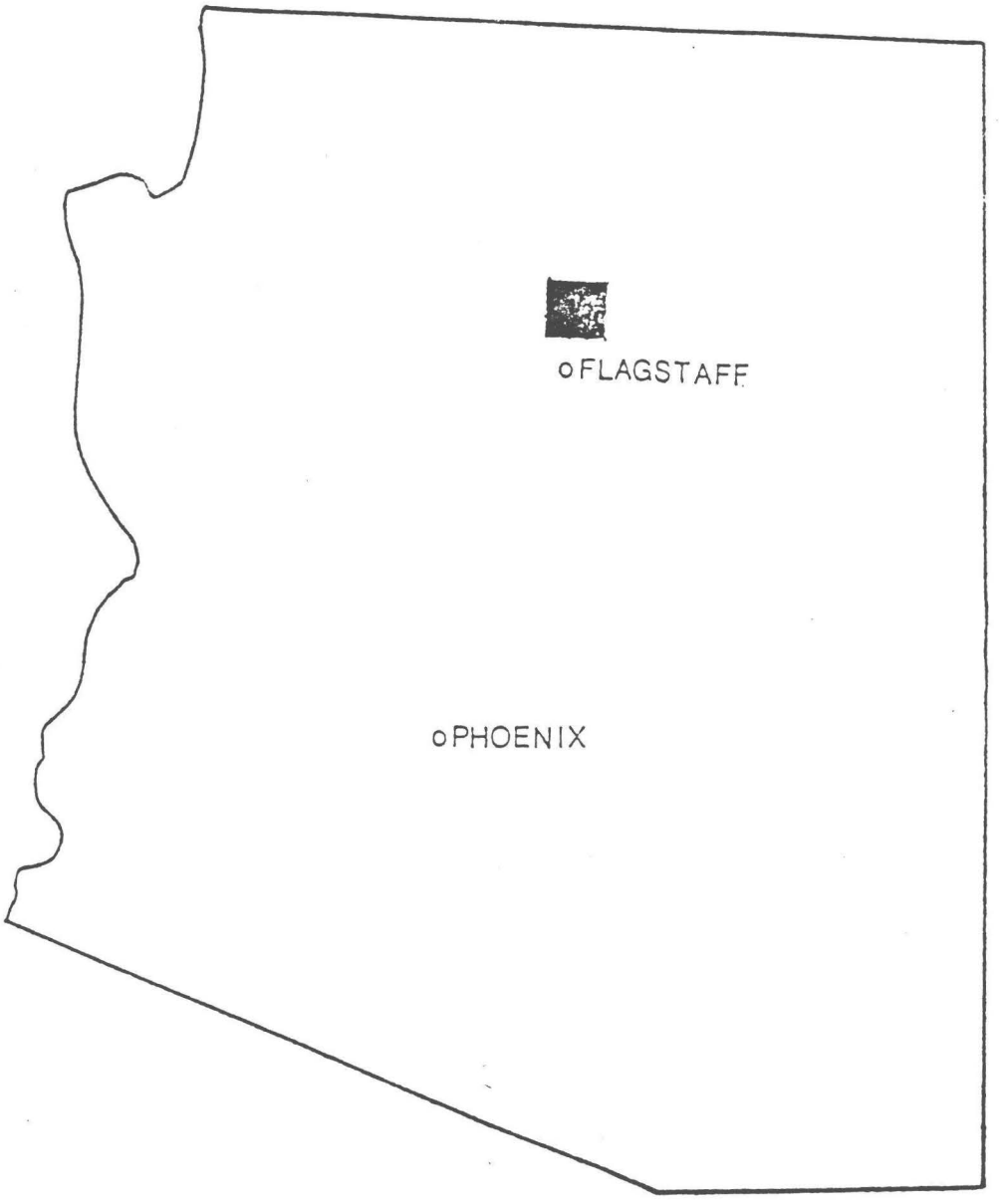

Figure 1. Location of Study Area.

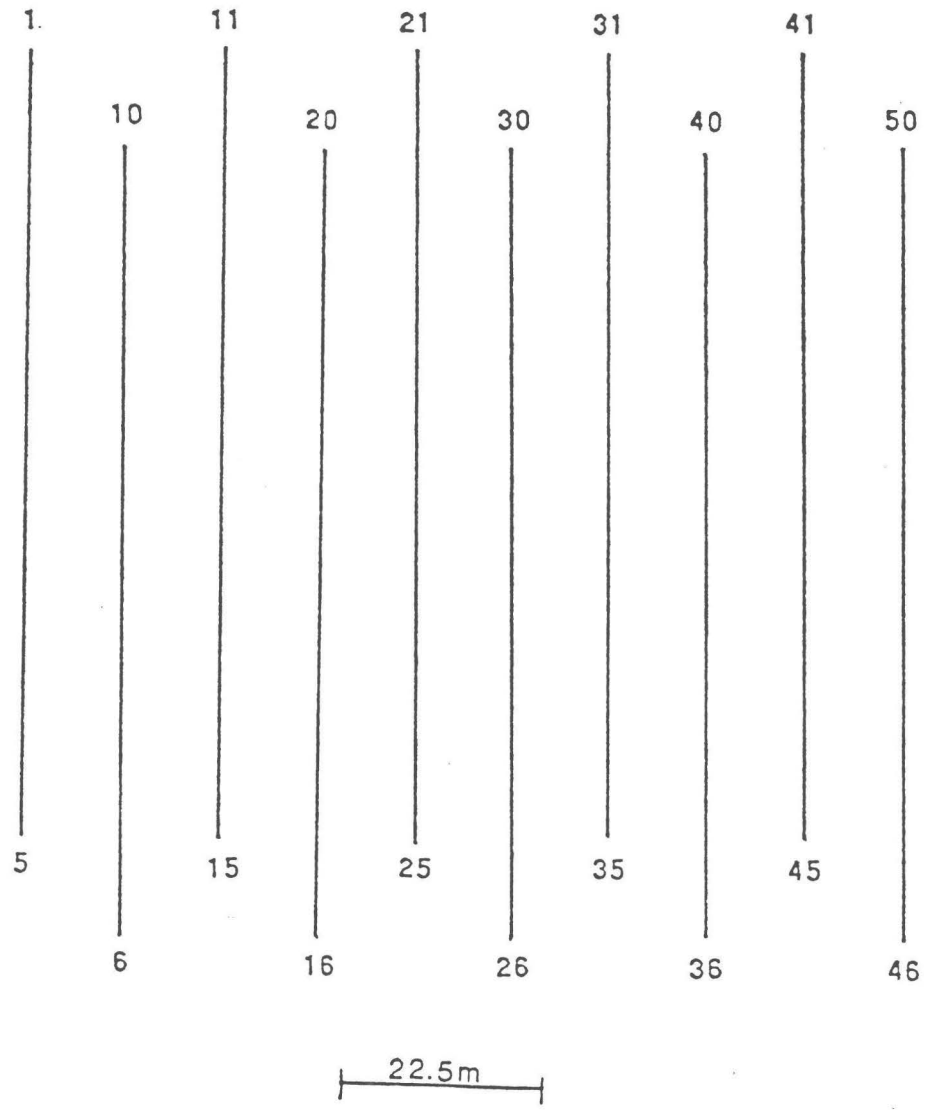

Figure 2. Example of Trap Layout in Staggered Configuration.

Table 1. Jolly-Seber (J-S) and Lincoln-Petersen (L-P) Population Density Estimates for Peromyscus spp. per Hectare for Owl Use and Non-use Areas in Two Spotted Owl Management Areas on the Peaks Ranger District of the Coconino National Forest, Arizona.

SITE[a]	GRID	J-S	L-P (s.e.)
1	1	6.22	8.75 (2.56)
1	2	4.50	9.00 (3.67)
1	3	6.59	14.00 (4.43)
2	1	7.88	15.00 (4.39)
2	2	3.33	5.00 (2.24)
2	3	3.67	10.50 (5.12)
3	1	17.13	17.78 (3.72)
3	2	5.22	9.00 (3.00)
3	3	9.13	11.20 (2.80)
4	1	7.73	9.00 (2.45)
4	2	7.56	9.00 (1.96)
4	3	3.67	2.67 (0.67)
5	1	5.89	8.75 (2.56)
5	2	7.33	11.20 (2.80)
5	3	7.42	10.00 (2.39)
6	1	8.10	9.14 (1.14)
6	2	7.38	11.67 (4.41)
6	3	4.75	15.00 (6.71)

[a]Site: 1=WeatherfordCanyonFeeding1; 2=WCF2 3=WCF3; 4=WCRandom1; 5=WCR2; 6=WCR3

Sites 1-3 are use areas; sites 4-6 are non-use

Table 1. (Continued)

SITE[a]	GRID	J-S	L-P (s.e.)
7	1	2.00	4.00 (2.45)
7	2	7.19	11.25 (3.75)
7	3	2.00	5.00 (3.16)
8	1	5.39	5.50 (2.87)
8	2	7.00	5.50 (2.87)
8	3	8.00	3.00 (1.41)
9	1	2.33	5.00 (3.16)
9	2	2.67	22.00 (14.83)
9	3	2.67	2.67 (0.67)
10	1	3.50	4.00 (1.63)
10	2	2.00	2.67 (0.67)
10	3	5.38	4.00 (1.41)
11	1	9.31	14.00 (4.04)
11	2	5.33	12.00 (5.20)
11	3	2.00	8.00 (4.00)
12	1	3.00	6.00 (2.00)
12	2	3.67	2.00 (0.82)
12	3	1.33	1.00 (0.00)

[a]Site: 7=SchultzCreekFeeding1; 8=SCF2; 9=SCF3; 10=SCRandom1; 11=SCR2; 12=SCR3

Sites 7-9 are use areas; sites 10-12 are non-use

Table 2. Average Jolly-Seber (J-S), Lincoln-Petersen (L-P) and Relative Abundance (R.A.) Plot Values in Numbers/ha for *Peromyscus* spp. on Use and Non-use Areas in Two Spotted Owl Management Areas on the Peaks Ranger District of the Coconino National Forest, Arizona.

SITE[a]	J-S	L-P	R.A.[b]
1	5.77	6.89	9.33
2	4.96	9.98	9.33
3	10.49	11.94	12.00
4	6.32	10.58	7.00
5	6.88	10.17	9.67
6	6.74	12.66	8.67
7	3.73	3.56	6.33
8	6.80	11.33	8.33
9	2.56	3.00	6.67
10	3.63	6.75	3.67
11	5.55	4.67	10.67
12	2.67	9.89	3.00

[a]Sites 1-3 and 7-9 are use areas, sites 4-6 and 10-12 are non-use

[b]R.A. is total number of prey animals trapped

Table 3. Results of Single Factor ANOVA on Various Estimates of Peromyscus spp. Populations from Use and Non-use Areas in Two Spotted Owl Management Areas on the Peaks Ranger District of the Coconino National Forest, Arizona.

Variable[a]	df	F-ratio	P-value
J-S	1,10	0.098	0.760
L-P	1,10	0.454	0.516
R.A.	1,10	1.004	0.340

[a]Variable: J-S=Jolly-Seber estimate; L-P=Lincoln-Petersen estimate; R.A.=Relative abundance estimate

Table 4. Average Plot Values for Various Habitat Components Measured on Use and Non-use Areas.

	VARIABLE[a]					
SITE	BA	LOGS	CC	TREES	GRASS	ROCK
1	9.70	22.23	56.83	194.9	16.27	3.90
2	19.74	39.52	61.74	244.3	20.52	1.32
3	14.46	29.64	57.49	277.1	13.37	4.93
4	15.24	9.88	55.86	227.3	13.39	1.15
5	20.07	19.76	53.74	463.9	21.63	1.33
6	15.41	41.99	51.12	211.2	29.57	4.23
7	19.62	49.40	60.11	307.3	12.57	14.13
8	22.55	76.57	64.84	299.1	17.20	9.10
9	17.23	44.46	66.97	304.6	15.17	12.73
10	22.92	24.70	43.37	356.7	20.70	3.97
11	20.97	51.87	62.23	219.6	18.02	10.87
12	25.42	71.63	71.54	214.3	18.87	3.50

[a]Variable: BA=basal area (m^2/ha);
LOGS=number oflogs/ha;
CC=% crown closure;
TREE=number of trees/ha;
GRASS=% grass present;
ROCK=% rock present

Table 4. (Continued)

	VARIABLE[a]					
SITE	LITTER	SPP	LGE	MED	SMALL	AVGDIAM
1	72.37	3.33	8.2	27.4	123.5	22.18
2	73.41	2.33	32.9	66.0	208.5	28.33
3	77.47	3.67	21.9	38.5	167.5	21.29
4	77.43	1.00	13.7	63.2	172.9	26.12
5	74.37	1.33	11.0	44.0	337.6	20.79
6	56.90	1.67	11.0	32.9	167.5	25.37
7	52.63	3.00	5.5	79.5	247.0	25.20
8	50.47	4.00	41.2	71.4	214.0	26.57
9	66.87	3.67	16.5	44.0	225.0	23.18
10	62.20	1.33	27.4	41.2	332.0	24.80
11	67.13	2.67	8.2	85.0	186.7	30.88
12	56.47	2.33	52.1	96.1	186.7	33.94

[a]Variable: LITTER=% litter present;
SPP=number of tree species present;
LGE=number of trees/ha >50cm;
MED=number of trees/ha >35cm;
SMALL=number of trees/ha >15cm;
AVGDIAM=average tree diameter

Table 5. Results of Single Factor ANOVA of Habitat Components Measured on Use and Non-use Areas in Two Spotted Owl Management Areas on the Peaks Ranger District of the Coconino National Forest, Arizona.

VARIABLE[a]	df	F-RATIO	P-VALUE
BA	1,10	1.245	0.291
LOGS	1,10	0.333	0.577
CC	1,10	1.377	0.268
TREES	1,10	0.060	0.819
GRASS	1,10	3.321	0.098
ROCK	1,10	1.905	0.198
LITTER	1,10	0.001	0.972
SPP	1,10	20.039	0.001
LGE	1,10	0.065	0.959
MED	1,10	0.037	0.668
SMALL	1,10	1.536	0.403
AVGDIAM	1,10	1.302	0.280

[a]Variable: BA=basal area (m^2/ha);
LOGS=number of logs/ha;
CC=% crown closure;
TREES=number of trees/ha;
GRASS=% grass present;
ROCK=% rock present;
LITTER=% litter present;
SPP=number of tree species present;
LGE=number of trees/ha >50cm;
MED=number of trees/ha >35cm;
SMALL=number of trees/ha >15cm;
AVGDIAM=average tree diameter

Table 6. Stand Characteristic Values for Spotted Owl Use Areas on the Peaks Ranger District of the Coconino National Forest, Arizona.

VARIABLE[a]	MEAN	MINIMUM	MAXIMUM	ST.DEV.
BA	18.61	9.70	25.42	4.38
LOGS	40.14	9.88	76.57	20.37
CC	58.82	43.37	71.54	7.54
TREES	267.67	194.90	463.9	77.05
GRASS	18.11	12.57	29.57	4.72
ROCK	5.93	1.15	14.13	4.58
LITTER	65.64	50.47	77.47	9.71
SPP	2.53	1.00	4.00	1.03
LGE	20.8	5.50	52.10	14.77
MED	57.43	27.4	96.1	22.43
SMALL	214.08	123.50	337.60	64.76
AVGDIAM	25.72	20.79	33.94	3.89

[a]Variable: BA=basal area (m^2/ha);
LOGS=number of logs/ha;
CC=% crown closure;
TREES=number of trees/ha;
GRASS=% grass present;
ROCK=% rock present;
LITTER=% of litter present;
SPP=number of tree species present;
LGE=number of trees/ha >50cm;
MED=number of trees/ha >35cm;
SMALL=number of trees/ha >15cm;
AVGDIAM=average tree diameter

Table 7. Pearson Correlation Coefficients for Habitat and Prey Data Collected on Two Spotted Owl Management Areas on the Peaks Ranger District of the Coconino National Forest, Arizona.

VARIABLE 1[a]	VARIABLE 2[b]	r-VALUE
RA	BA	-0.529
RA	LITTER	0.500
L-P	ROCK	-0.708

[a]Variable 1: RA=relative abundance estimate;
L-P=Lincoln-Petersen estimate

[b]Variable 2: BA=basal area (m^2/ha);
LITTER=% litter present;
ROCK=% rock present

Table 8. Stand Characteristic Values for Comparison of this study with a Previous Spotted Owl Study Conducted by J. Ganey (1988).

VARIABLE[a]	THIS STUDY[b]	FORAGE SITE	RANDOM SITE
BA	18.61	47.53	32.3
LOGS	40.14	86.50	44.50
TREES	267.67	646.70	445.30
CC	58.82	67.10	51.7
ELEV	2418	2287[c]	2170

[a]Variable: BA=basal area (m^2/ha);
LOGS=number of logs/ha;
TREES=number of trees/ha;
CC=% crown closure;
ELEV=average elevation in m

[b]Sites for this study are forage sites

[c]Elevation is not specifically for a forage site; it is given for areas where owls were located.

APPENDIX 1

MINIMUM STAND REQUIREMENTS FOR OLD GROWTH IN PONDEROSA PINE FOREST COVER TYPE

Factor	Low Site (SI <55)	High Site (SI >55)
1. Live Trees		
a. Large		
Number/ha	49 or 30	49 or 35
	@ @	@ @
DBH (cm)	36 46	51 61
Age[1]	150	160
BA (m^2/ha)	14	25
b. Canopy Cover (%) (all live trees)	45	60
2. Dead Trees		
a. Standing		
Number/ha	4.5	4.5
DBH (cm)	36	36
Height (m)	4.5	10.7
b. Down logs		
Number/ha	4.9	4.9
Diameter (cm)	30	30
Length (m)	4.5	4.9

[1] Stand average must be 120 years (sawtimber class).

Height: The total span of a dead standing tree measured in meters from ground level along the bole on the uphill side of the tree to the tip of the tree, if merchantable. For nonsound dead trees with broken tops, height is measured to the broken top and the missing portions is ignored.

Down Logs: Dead trees that are lying on the forest floor. They may be in tree length or broken into several sections.

APPENDIX 2

SELECTED STAND CHARACTERISTICS OF OLD GROWTH PONDEROSA PINE HABITAT TYPE AREAS OCCUPIED BY SPOTTED OWLS IN ARIZONA (Ganey 1988)

Factor	Measurement
1. Live Trees	
Number/ha	498.9
Basal area (m^2/ha)	42.3
Canopy cover (%)	57.4
2. Standing Dead Trees	
Number/ha	55
Basal area (m^2/ha)	5.14
3. Down Logs	
Number/ha	49

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